EDDA

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D7.6: EXECUTIVE SUMMARY

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Abstract

European Direct Drive Architecture (EDDA) project has demonstrated the feasibility and the major benefits to introduce Direct Drive in the future high power electrical propulsion systems.

EDDA allows satellite electrical power supply design simplification, cost reduction, optimization of solar array power, and significant reduction of the power dissipation. No show stopper is identified for thrusters at high voltage (250-400 V) and at high power (up to 20 KW).

Demonstration has been successfully performed with both Hall Effect Thruster and High Efficiency Multistage Plasma Thruster technologies fired in a double configuration at 5 KW. Future studies are proposed to increase the current TRL 4 status up to TRL-8 (possibly with In Orbit Demonstration).

The optimized propulsion systems enabled by EDDA will allow to seize new opportunities in telecommunications, on-orbit servicing and space exploration. EDDA is a really promising solution for future high power systems.

Applicable and Reference documents

AD#	Reference	Title
AD01		Grant Agreement 870470 EDDA

RD#	Reference	Title

The European space sector supports innovative technologies to improve the performance of future spacecraft.

European Direct Drive Architecture (EDDA) study shows an efficient way to simplify power supply of electric propulsion (EP) at high voltage. A dc converter is removed and solar array maximum power at beginning of life is accessible. Today both improve power capability by 10 to 20% for a similar configuration. Power electronics in Power Processing Unit (to supply thrusters) and Power Conditioning Unit (conditioning solar array power) are simplified with significant saving on cost, mass and dissipation and a better end to end efficiency (advantage at spacecraft level)

The main characteristic is a bus voltage increase (250V minimum voltage for thruster in nominal conditions - 400V maximum today achievable solar array voltage) compatible with several electric thrusters (at least those used in this study, namely two 5kW Hall Effect Thrusters manufactured by Sitael and one 5 kW High Efficient Multistage Plasma Thruster, manufactured by Thales-D). In this part of voltage range, thrusters have their best thrust/power ratio.

Arcing is the main risk of the Electrical Direct Drive Architecture due to the high voltage to be driven from the Solar Array up to the electrical thrusters.
Arcing may occur in different phases:

- during launch at the minimum Paschen pressure (~1mbar above 100km altitude)
- during outgazing (in early phase after launch if any material degradation occurred)
- or outside the spacecraft due to environment, mainly on the solar array.

Design rules are well known to mitigate this risk and they have to be implemented and qualified in representative environment.

The design rules for solar panels were evaluated in a previous H2020 study named HV-EPSA (High Voltage Electrical Power System Architecture). This study as well as return of experience give confidence to mitigate arcing risks.

Increased voltage can be withstood from power components point of view: currently as in existing Power Processing Unit (driving current thrusters), or enhanced MOS ones, or also in GaN.

Modelling helps during design to forecast thruster characteristics such as impedance and anode current oscillations, with a high level a representativity. More accurate Ground or in flight plasma discharge modellings enable a better understanding of any plasma phenomena and their impacts on overall performances.

Modularity is also a key factor for satellite design optimization with regards to the need during the mission phases and tolerance to failure cases: with 3 levels of thruster power (1kW, 5 to 7 kW, 20kW), it is possible to cover a spacecraft need from 1 kW to 100kW of Electric Propulsion (ex : 100kW : 5 thrusters of 20kW or 30kW : 6 thrusters of 5 kW). EDDA tested the simultaneous use of 2 thrusters of 5kW - see figure 1 - with independent control of their power. Chosen architecture does not limit the number of thrusters used at the same time.

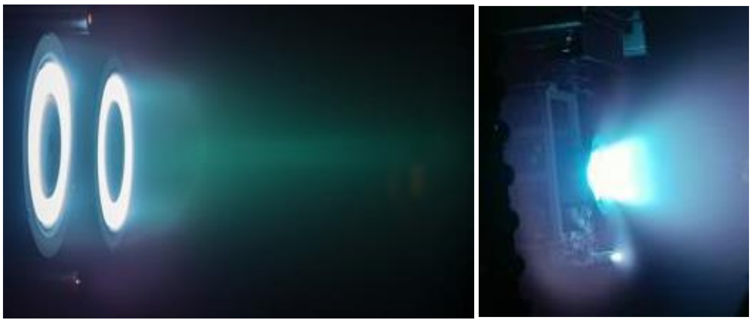

Figure 1 : EDDA versatility, for number of thrusters used simultaneously (2 x HT 5k from Sitael on left picture), for compatibility with various technologies (HEMPT 5kW on the right).

A cathode supply adapts cathode potential to get equilibrium between anode current and cathode current to avoid stray current. This cathode potential may be positive or negative depending on configuration and environment. This requires a two-quadrant cathode supply. Further investigations shall be done based on theory as well as already experimented situations on Ground and in flight since Smart 1 mission.

Power bus cleanliness depends at first order on power delivered to the thrusters and their setting points as magnetic fields for HETs, which should be tunable in flight. During the coupled tests, an EMC susceptibility was observed when the electronics was floating compared to the Earth. When the test was grounded to the Earth, most of the perturbations were removed. Better understanding of bus susceptibility thruster emissions and coupling phenomena in flight configurations shall be further analyzed, and even better tested in real conditions with an In Orbit Demonstration.

A maximum peak power tracking (MPPT) regulation and its bus voltage range as well as a fixed bus voltage (as can provide a Sequential Switching Shunt Regulator-S3R, extensively used on Geo Telecom Satellites), are both compatible with Direct Drive as tested during EDDA. "Jump" from one regulation to the other one has been tested as this could happen during a flight (EOR to GEO or GEO to SAFE , in figure 2).

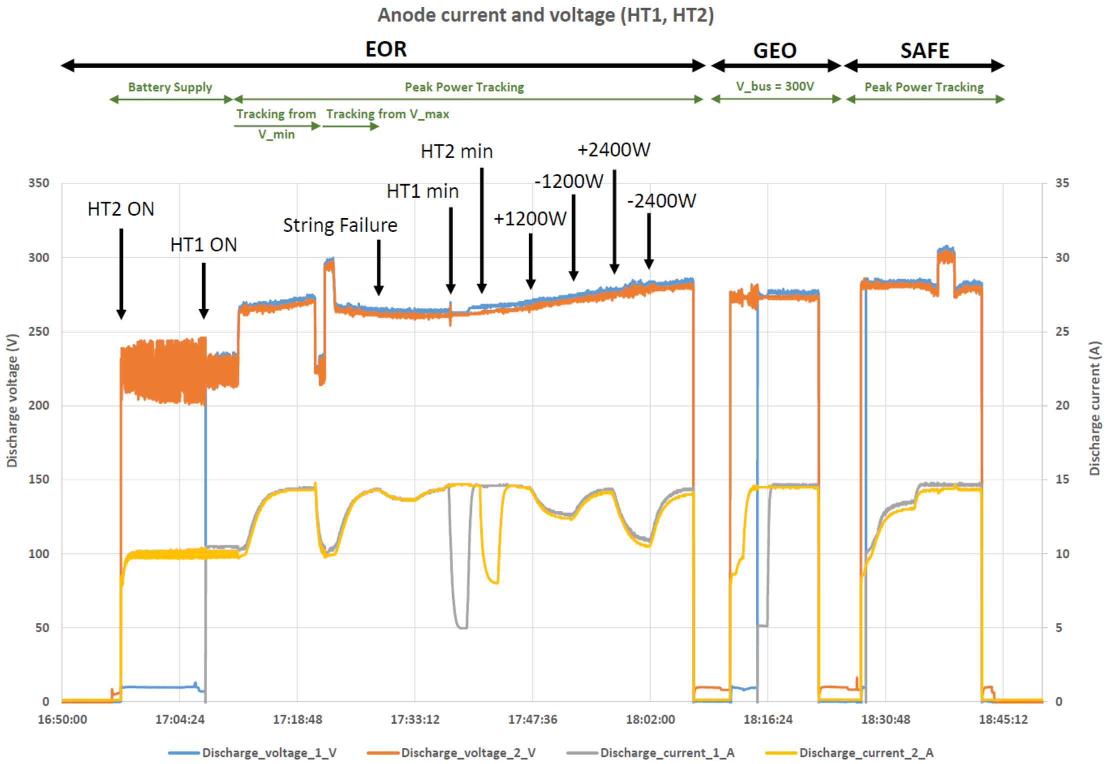

Figure 2 : Anode and cathode currents for 2 HETs during test sequenced

Tests were specified to correspond to operational phase of a Geo telecom satellite (stringent configuration with respect to other missions), depicted in figure 2.

From launch to Geostationary orbit, Electric Orbit Raising (EOR) requests a maximum power from the solar array.

- MPPT behavior was tested from minimum then maximum solar array voltage to verify that the maximum power was reached (see “tracking for V min” and “tracking from V max” on figure 2).
- a solar string failure (-1.5A) was simulated,
- HT1 power was decreased (“HT1 min”), then back to max. And then HT2 power was decreased (“HT2 Min”), then back to max
- 4 variations of satellite consumption (+1200W, -1200W, +2400W, -2400W) are tested, showing adaptation of Electric Propulsion power to stay at solar array maximum power

In GEO, thrusters are turned off corresponding to an arrival in final orbit to switch to constant voltage (MPPT->S3R) with a thruster ignition as during station keeping maneuvers.

To simulate a SAFE mode, MPPT is activated to have a maximum power dedicated to Electric Propulsion during a safe mode.

EDDA has been a great study to increase TRL up to 4. Based on its successful results, further activities have to be planned to go to TRL 8 or 9. In Orbit Demonstration is one of the ways to achieve it.